SASK
MAY 7
REGINA

This report has been prepared primarily for internal use by Saskatchewan Government agencies. Material should not be used without approval.

HYD-4-8

WOOD RIVER NEAR GRAVELBOURG

HYDROLOGY STUDY

By: H. E. Mahood, P. Eng.
Investigation Division
Hydrology Branch
Saskatchewan Environment

October, 1981

SYNOPSIS

As part of the Canada-Saskatchewan Flood Damage Reduction (FDR) Program, a study of the potential flood flows below Thomson Reservoir has been carried out.

Hydrometric data for the Wood River were analysed to arrive at runoff volume and peak flow estimates for the 10, 25, 50, 100 and 500 year events for inflow to the reservoir. Flood hydrographs for each of the floods of interest were then routed through Thomson Reservoir, and the resulting outflow hydrograph was simulated. Mean daily and instantaneous peak flows were considered identical in the outflow hydrographs.

CONTENTS

		Page
	SYNOPSIS	
I	INTRODUCTION	1
	A. BACKGROUND TO THE STUDY	1
	B. BASIN DESCRIPTION	1
	C. HISTORICAL FLOODING	2
II	BASIN RUNOFF POTENTIAL	5
	A. HYDROMETRIC AND RESERVOIR DATA	5
	B. INFLOW TO THOMSON RESERVOIR	6
	1. Runoff Volumes	6
	2. Peak Flows	9
	3. Flood Hydrographs	11
III	FLOOD ROUTING	13
	A. RESERVOIR OPERATION	13
	B. RESULTS OF THE FLOOD ROUTING	14

TABLES

TABLE 1	POTENTIAL FLOOD VOLUME AND PEAK FLOWS FOR WOOD RIVER ABOVE THOMSON RESERVOIR UNDER PRESENT CONDITIONS	11
TABLE 2	THOMSON RESERVOIR MAXIMUM DAILY OUTFLOW MAXIMUM WATER LEVEL, AND DURATION OF HIGH OUTFLOW FOR VARIOUS FLOOD MAGNITUDES	15

ILLUSTRATIONS

FIGURE 1	KEY MAP OF WOOD RIVER BASIN ABOVE THOMSON RESERVOIR
FIGURE 2	THOMSON RESERVOIR SPILLWAY DISCHARGE AND STORAGE CAPACITY
FIGURE 3	WOOD RIVER NEAR LAFLECHE NATURAL ANNUAL RUNOFF VOLUME FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON GUMBEL PROBABILITY PAPER
FIGURE 4	WOOD RIVER NEAR LAFLECHE NATURAL ANNUAL RUNOFF VOLUME FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON LOG PROBABILITY PAPER

FIGURE 5 WOOD RIVER NEAR LAFLECHE PEAK DAILY DISCHARGE FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON GUMBEL PROBABILITY PAPER

FIGURE 6 WOOD RIVER NEAR LAFLECHE PEAK DAILY DISCHARGE FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON LOG PROBABILITY PAPER

FIGURE 7 WOOD RIVER BELOW THOMSON RESERVOIR FLOOD HYDROGRAPHS FOR 10, 25, 50, 100 and 500 YEAR FLOOD EVENTS

I

INTRODUCTION

A. BACKGROUND TO THE STUDY

In the Gravelbourg area, the Wood River has a rather extensive flood plain which is often inundated during the larger spring runoff events. Lafleche Dam, completed in 1957 and forming Thomson Reservoir, is located upstream from and about six miles south of Gravelbourg. This means that Wood River flows through the area are now modified to some extent by passing through the reservoir.

The Hydrology Branch of Saskatchewan Environment was requested to undertake a hydrological study, as part of the Canada-Saskatchewan Flood Damage Reduction (FDR) Program, of flood flows in the Wood River below Thomson Reservoir. Presented in this report are the results of the study, including hydrographs for the 10, 25, 50, 100 and 500 year flood events in the Wood River below Thomson Reservoir.

B. BASIN DESCRIPTION

The Wood River has its source in the height of land which separates southward drainage into the Frenchman River, and eventually the Missouri River, from northward drainage into Old Wives Lake.

A key map of the Wood River basin above Thomson Reservoir is shown on Figure 1. After it turns from an easterly to a northerly

flowing stream, the Wood River is joined by a number of tributary creeks. Pinto Creek is one such tributary, which drains a large area in the western part of the basin and joins the Wood River a short distance upstream from Thomson Reservoir. Downstream from the Pinto Creek confluence, as far as Gravelbourg, there are no other major tributaries.

The Wood River basin above Thomson Reservoir drains a relatively large area of farm and ranch land in southwestern Saskatchewan, in which the natural vegetation is open grassland. The climate can be described as semi-arid with most of the annual streamflow occurring each spring as a result of winter snowmelt, augmented in many years by spring rain. The basin is characterized by positive slopes and relatively few depressional areas, with total relief exceeding 1,000 feet or 300 metres. There is also a high ratio of effective to gross[1/] drainage area, which indicates that only a small portion of the basin does not contribute to streamflow in a normal year.

C. HISTORICAL FLOODING

The urban community of Gravelbourg had its beginning around the year 1906. Conversations with long time residents indicate that the town has never really been flooded from the outside.

1/ The "effective" drainage area is that area of a basin which might be expected to contribute runoff to the main stream in an average or normal runoff year.

The "gross" drainage area is the area which may contribute to streamflow under extremely wet conditions, but which also defines the boundaries between two watersheds.

Since the town was originally built in a slough or depressional area, direct precipitation could, at times, have caused some ponding. This problem would now be largely overcome by the town's present storm sewer capability. While land in the immediate vicinity, particularly southeast of the present built up area, has been inundated flood damage within the town under worst conditions has been small, and probably limited to basement flooding.

There are strong indications that the flooding of land adjacent to the Town of Gravelbourg has been a relatively common occurrence. In a local newspaper article dated 1955[2/] on the history of Gravelbourg, mention is made of flooding in the spring of 1907, and of an equally high water level in 1923. A very high peak flow in the Wood River near Gravelbourg occurred in 1925, which has since been exceeded, among years of record, only in 1952.

According to local residents who experienced the 1952 flood, Wood River flow through the CNR bridge east of Gravelbourg was restricted due to floating ice and debris, and a large area east and south of Gravelbourg was inundated to form a temporary lake. Despite the record high 1952 flood levels, above ground flooding probably did not occur within the town, and in fact no such event was reported[3/] in the local newspaper, the Gravelbourg Star.

2/ The Prairie Optimist News Special Golden Jubilee Issue, dated May 26, 1955.

3/ There is a brief item in the April 20, 1952 edition of the Star which refers to flooded basements, and in the April 24 edition appreciation is expressed to employees who kept the disposal plant operating during the previous two weeks of flooding. If there had been extensive above ground flooding, it would likely have been reported in one or both of these editions of the local newspaper.

Since 1952 there have been changes which would affect flow conditions through the area. The CNR bridge has been widened with more clearance. Thomson Reservoir, now in place upstream of the area, would tend to eliminate floating ice as a problem and to modify instantaneous peaks coming from upstream. For these reasons a 1952 magnitude of flood flow now would probably not result in water levels at Gravelbourg as high as those which occurred in that particular year.

II

BASIN RUNOFF POTENTIAL

A. HYDROMETRIC AND RESERVOIR DATA

In the study, use was made of the published Water Survey of Canada (WSC) records for Wood River flow in the study area. The location of the former WSC station, Wood River near Gravelbourg, is downstream from the present Thomson Reservoir, and flows there were recorded for the years 1918 through 1925, 1936, and for two months during the year 1940. The present WSC station, Wood River near Lafleche, is located immediately upstream from Thomson Reservoir and flows have been recorded continuously for that station starting in 1944.

Included in the available data was a set of reconstructed natural flow volumes for the Wood River near Lafleche for the 56 year period 1917-72 inclusive, prepared by PFRA, Hydrology Division, and tabulated in their Hydrology Report No. 69[4/]. Along with recorded flows, this provided a 63 year study period 1917-79 inclusive for Wood River runoff. It was felt that this length of period was adequate for the study, and that no particular advantage would be gained by attempting to extend the record to earlier years.

Curves relating water level in Thomson Reservoir to storage capacity and spillway discharge were obtained from reservoir

---

4/ Report on Water Supply Study for the Proposed Willow Bunch Thermal Power Project, Hydrology Report No. 69, July, 1974. PFRA, Hydrology Division

"as constructed" plans, and are shown on Figure 2. The five spillway gates, which have a sill level that is seven feet or 2.13 metres below full the supply level of 2345.0 feet (714.76 m.), allow for a wide range in reservoir outflow. The riparian outlet, for which a discharge curve was also available, would normally be kept closed during spring runoff. Its discharge capacity is quite small and, even if open, its potential effect on the reservoir during major flood flows would be insignificant.

B. INFLOW TO THOMSON RESERVOIR

1. Runoff Volumes

With no major storage and minimal other project development in the basin at that time, the recorded flows at the former Wood River station near Gravelbourg were accepted as a close approximation of natural flows for the years 1918-25 inclusive and for 1936. Natural flows for the remaining years in the period 1917-72 inclusive, as estimated by PFRA, were also used. For the years following 1972, natural flows were estimated by use of a graphical correlation between natural and recorded flow volumes for the overlapping years 1944 through 1972.

Natural runoff volumes for the Wood River near Lafleche for the 63 year period 1917-79 inclusive, were tabulated, and a plotting position assigned to each value based on its relative magnitude. A frequency curve was drawn for these volumes on Gumbel probability paper. Values for years in which flows were not recorded at either the Gravelbourg or

Lafleche stations were not plotted, but were used for plotting position only. The same array was also plotted on logarithmic probability paper, and a best fit straight line was drawn through the plotted points which represented a 1:2 or larger runoff magnitude.

The array of natural flood volumes was also analyzed using the FDR Program frequency analysis[5/] for the following flood frequency distributions: Gumbel 1, Log Normal, Three Parameter Log-Normal, and Log Pearson Type III fitted by both maximum likelihood and the method of moments. In these mathematical solutions, all figures in the array are assumed of equal value, and it is not possible to give more weight to figures representing recorded, as opposed to completely estimated, flows. There was a relatively wide range of difference in the results of the analysis using the different methods and distributions. These mathematically derived curves, along with the two manually derived curves previously mentioned, were then drawn up for comparison purposes on both Gumbel and Log probability paper, along with the plotted points representing recorded annual runoff volumes.

The reference, in this method of comparing the various curves, is the collective position of the plotted points which, as

---

5/ Engineering Hydrology Section, Engineering Division, Water Planning and Management Branch, Inland Waters Directorate, Environment Canada, "Flood Damage Reduction Program Flood Frequency Analysis" R. Condie, G. A. Nix and L. G. Boone, Ottawa, Ontario, June, 1976.

previously mentioned, represents measured as opposed to estimated data. Since the two manually derived curves were, in the first instance, drawn up on the basis of these plotted points, they may conceivably fit the known or measured data more closely than the mathematically derived curves.

The various annual runoff curves and plotted points are shown on Gumbel and Log probability paper on Figures 3 and 4 respectively. The manually drawn Gumbel curve, No. 4, was selected as the "best fit" curve for the study. For example, it was considered to more closely fit the plotted points than the two nearest curves, namely number 3 on the high, and number 5 on the low side, as shown on both Figures 3 and 4.

Inflow to Thomson Reservoir under present conditions is somewhat different than natural flow in the Wood River near Lafleche. Such natural flows have been reduced by the extent of upstream diversion, but also increased by local runoff to the reservoir which occurs downstream of the Lafleche station. Local annual inflow to the reservoir was estimated from known flows at the Lafleche station, based on relative size of their respective drainage areas. A drainage area factor of 0.68 for the local area was estimated as applicable to all runoff volumes up to and including the 1:500 magnitude. The required flood volume magnitudes at Thomson Reservoir were estimated by allowing for the above-mentioned differences to natural flow at the Lafleche station.

2. Peak Flows

Records of peak daily flow in the Wood River were available for a total of 10 years at the former hydrometric station near Gravelbourg, and for a continuous 36 year period at the present station near Lafleche. To estimate peak flows for the missing years of record in the 63 year study period, 1917-79 inclusive, use was made of a good graphical correlation between natural annual runoff volumes and recorded peak daily flows.

For purposes of the study, it was assumed that peak daily flows at the Lafleche station would not be significantly different to the corresponding inflow peaks at the reservoir, since both local runoff and upstream diversion would normally occur early in the runoff cycle before the occurrence of the overall peak at either location. The same would apply to peak flows recorded at the former station near Gravelbourg, keeping in mind that, for those years in which the station was operated, Thomson Reservoir was not yet in existence and, therefore, not an influence upon downstream flows.

Peak daily flows for the 63 year study period were tabulated, and a plotting position assigned to each based on its relative magnitude. A frequency curve was drawn up on each of Gumbel and logarithmic probability paper, and for both curves the only points plotted were those representing years of recorded flow.

The flood peak array was also analysed mathematically by use of the FDR Frequency Analysis Program which gives results for various distributions provided for in the program. As in the flood volume analysis, there was a wide range of difference in these calculated results. For example, the Log Pearson III by moments had a flood estimate of zero for all magnitudes, the mathematically derived Gumbel 1 had an estimate of the 500 year flood peak which was lower than the highest peak flow during the 63 year study period. At the other extreme the mathematically derived log normal distribution gave an estimate of the 500 year flood peak which was more than five times the highest peak flow during the study period. Curves were drawn for each of the various mathematical solutions along with the two manually derived curves, on each of Gumbel and Log probability paper in which the points representing individual recorded peak flows had been plotted. These graphical representations of the various curves and the plotted points are shown on Figures 5 and 6 on Gumbel and Log probability paper, respectively. Using this comparison, it was concluded that the original manually drawn Gumbel curve No. 4 does, in fact, best fit the plotted points, and values from that curve were accepted as the "best estimates" for purposes of the study.

Under present conditions, instantaneous peak flows at the Lafleche station would always be modified in passing through Thomson Reservoir. Downstream from Thomson Reservoir in major runoff events the flood plain becomes inundated, also acting

as a reservoir, so instantaneous peaks originating there from local runoff would be modified, and have no significant impact on the flooding condition. From the viewpoint of potential flooding at Gravelbourg, it was felt that any analysis of instantaneous peak flows would not be useful or significant and, therefore, this refinement was omitted from the study.

Table 1 summarizes the results of the flood frequency analysis for inflow to Thomson Reservoir for floods ranging from the 1:2 6/ to the 1:500 runoff event.

TABLE 1

POTENTIAL FLOOD VOLUME AND PEAK FLOW FOR
WOOD RIVER ABOVE THOMSON RESERVOIR
UNDER PRESENT CONDITIONS

Probability in Any One Year is:	That the Mean Daily Peak Flow will Equal or Exceed:		And that the Runoff Volume will Equal or Exceed:	
	cfs	m^3/s	acre-feet	dam^3
1:2	1550	41.5	33400	41200
1:10	5200	146	98000	121000
1:25	7600	215	141000	174000
1:50	9600	272	172000	212000
1:100	11600	351	206000	255000
1:500	16500	467	285000	351000

6/ Although not requested by the FDR Steering Committee, values for the 1:2 runoff magnitude were estimated in the course of the study. By including these figures in Table 1 a more complete range of runoff events is indicated.

3. Flood Hydrographs

Shaping of theoretical flood hydrographs for the Wood River above Thomson Reservoir was based on the shape of recorded hydrographs at the present and former hydrometric stations, both located on the Wood River a short distance from the present reservoir. Four of the larger flood hydrographs on record, those for 1925, 1952, 1969 and 1976 were plotted on each of the rising and recession limbs, which would be representative or characteristic of the slope of the respective limbs of four plotted hydrographs. Typical slopes evaluated in this way were 2 days per log cycle for the rising limb and 11 days per log cycle for the recession. These typical or characteristic slopes were than used along with peak flow and volume [7], already estimated to construct the required daily flow hydrographs for 1:10, 1:25, 1:50, 1:100 and 1:500 flood events in the Wood River above Thomson Reservoir.

7/ It was assumed in constructing theoretical hydrographs that there is a direct relationship between a given magnitude of runoff volume and flood peak, in which for example a 1:25 flood event will feature that magnitude of both runoff volume and peak flow. This is considered valid for the purpose of the study, but has limitations when applied to some individual years, in which for example, a 1:10 flood volume could occur along with a 1:25 peak flow, while in another year these particular magnitudes of volume and peak could be reversed.

III

FLOOD ROUTING

A. RESERVOIR OPERATION

For flood routing the initial or pre-spring runoff level in Thomson Reservoir was assumed to be 1.7 feet or 0.518 metres below FSL, to allow for an average depth of net evaporation during the preceding year. This was considered a reasonable allowance for actual conditions. However, in an extremely large flood, the initial reservoir elevation does not appear to be a critical factor. For example, in the 1:500 flood event, it was found that the reservoir reached exactly the same peak level on the same day of the runoff cycle, whether the initial level was taken as mentioned above or at the reservoir FSL. Evidently, the additional storage capacity provided by the lower starting elevation is too small, in relation to inflow magnitudes, to have any appreciable impact on the overall reservoir balance.

Generally, in any major flood, the five spillway gates would likely be opened early in the runoff cycle to draw down the reservoir in order to avoid an unwanted and unnecessary later build up of reservoir levels. For a very large flood, the exact timing of this gate opening may not be too critical, however. For example, in routing through the 1:500 flood, it was found that the reservoir reached exactly the same maximum level on the same day of runoff, whether the five gates were opened on the first day of runoff or

opened three days earlier. For floods of a 1:50 and larger magnitude, it was assumed for purposes of study, that the spillway gates would be opened on Day No. 1 of the runoff period. For the smaller runoff events, such as a 1:10 and 1:25, it was assumed that the gates would be left closed until the reservoir level approached FSL, since a priority under lower runoff conditions would be to fill the reservoir.

After the flood peak had passed and the reservoir had dropped to a level approaching FSL, it was assumed that the spillway gates would be operated in a way which would stabilize levels at or near FSL. In effect, this would mean that, for this part of the recession, daily inflow and outflow are balanced and equal.

B. RESULTS OF THE FLOOD ROUTING

Daily flow hydrographs for each of the 1:10, 1:25, 1:50, 1:100 and 1:500 flood events were routed through Thomson Reservoir. Flood routing calculations were based on the Puls method of flood routing, in which daily inflow values were added to storage, and the resulting outflow hydrograph was simulated.

The results of routing the above-mentioned flood flows through Thomson Reservoir are shown graphically on Figure 7, and are summarized in Table 2. There is some variation in timing of the rising limb, among the various hydrographs shown on Figure 7. These variations, which occur from routing different hydrographs through reservoir storage and from different reservoir operation during the early stages of runoff, are not significant to the purpose and results of the study.

Corresponding peak flow figures for given floods in Tables 1 and 2 indicate that the routing of floods through Thomson Reservoir will not diminish the magnitude of daily mean peaks for the 10 and 25 year outflow hydrographs, and will only slightly diminish peaks for the three larger events listed. This relatively small difference in modification of peaks between the smaller and larger floods can be attributed to the increasingly larger surface area and storage capacity of the reservoir at higher water elevations. However, even for the larger floods, such as the 50, 100 and 500 year events, the increased storage capacity of the reservoir at higher elevations is still too small to have a major effect in modifying daily peak flows.

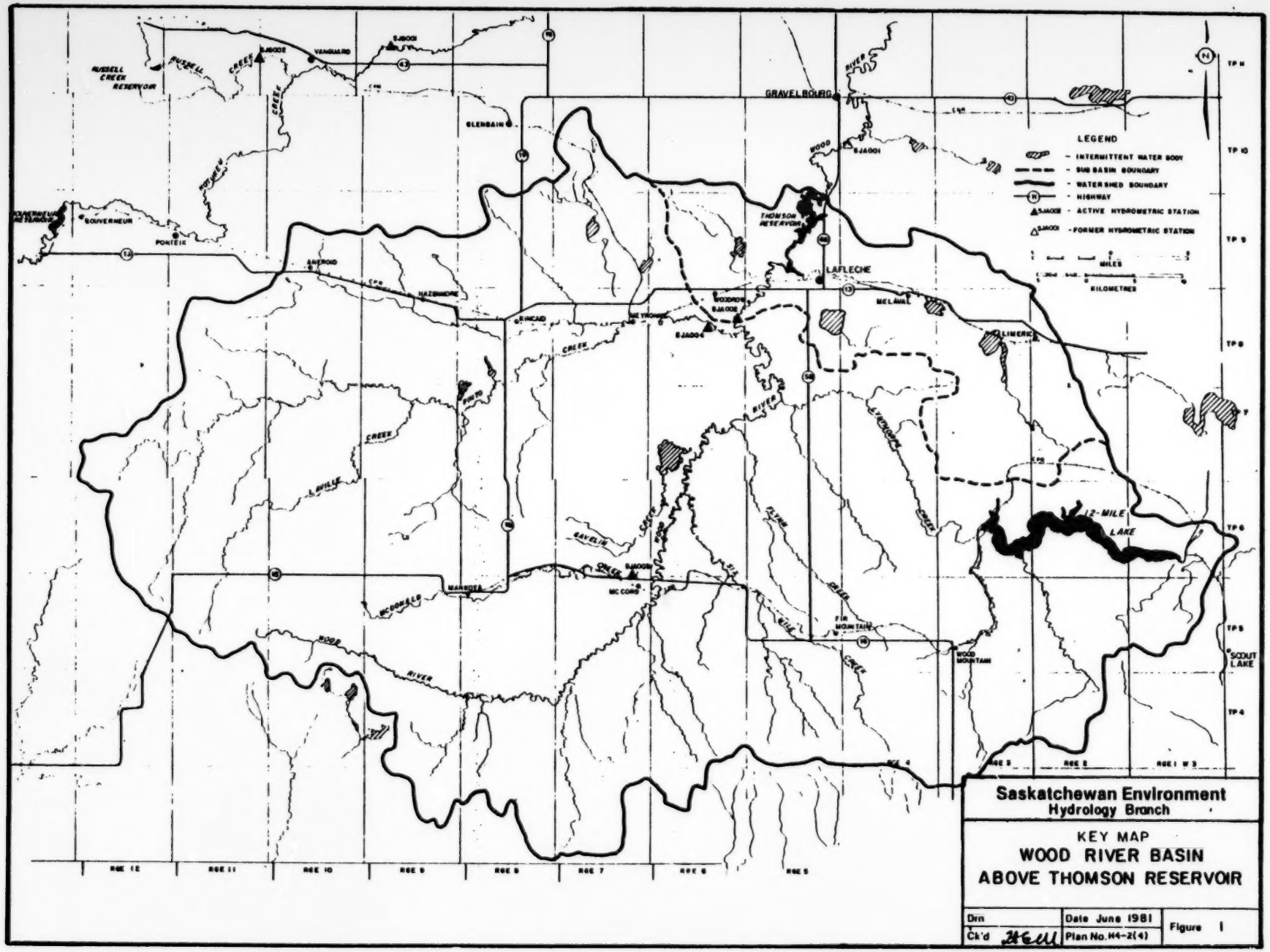
TABLE 2

THOMSON RESERVOIR MAXIMUM DAILY OUTFLOW,
MAXIMUM WATER LEVEL, AND DURATION
OF HIGH OUTFLOW FOR VARIOUS FLOOD MAGNITUDES

Flood Magnitude	Maximum Daily Reservoir Outflow		Maximum Reservoir Water Level		No. Days with Outflow of 5000 cfs($142 m^3/s$) or more
	cfs	m^3/s	feet	meters	
1:10	5200	147	2345.0[8/]	714.76	4
1:25	7600	215	2345.0[8/]	714.76	6
1:50	9300	263	2346.9	715.32	7
1:100	11250	319	2348.0	715.68	8
1:500	15780	447	2350.5	716.44	10

8/ For smaller floods such as a 1:10 and 1:25, an analysis of detailed gate operation was not required, but it was recognized that the gates could be operated in such a way as to keep the maximum reservoir elevation at or close to FSL of 2345.0 feet (714.76 m).

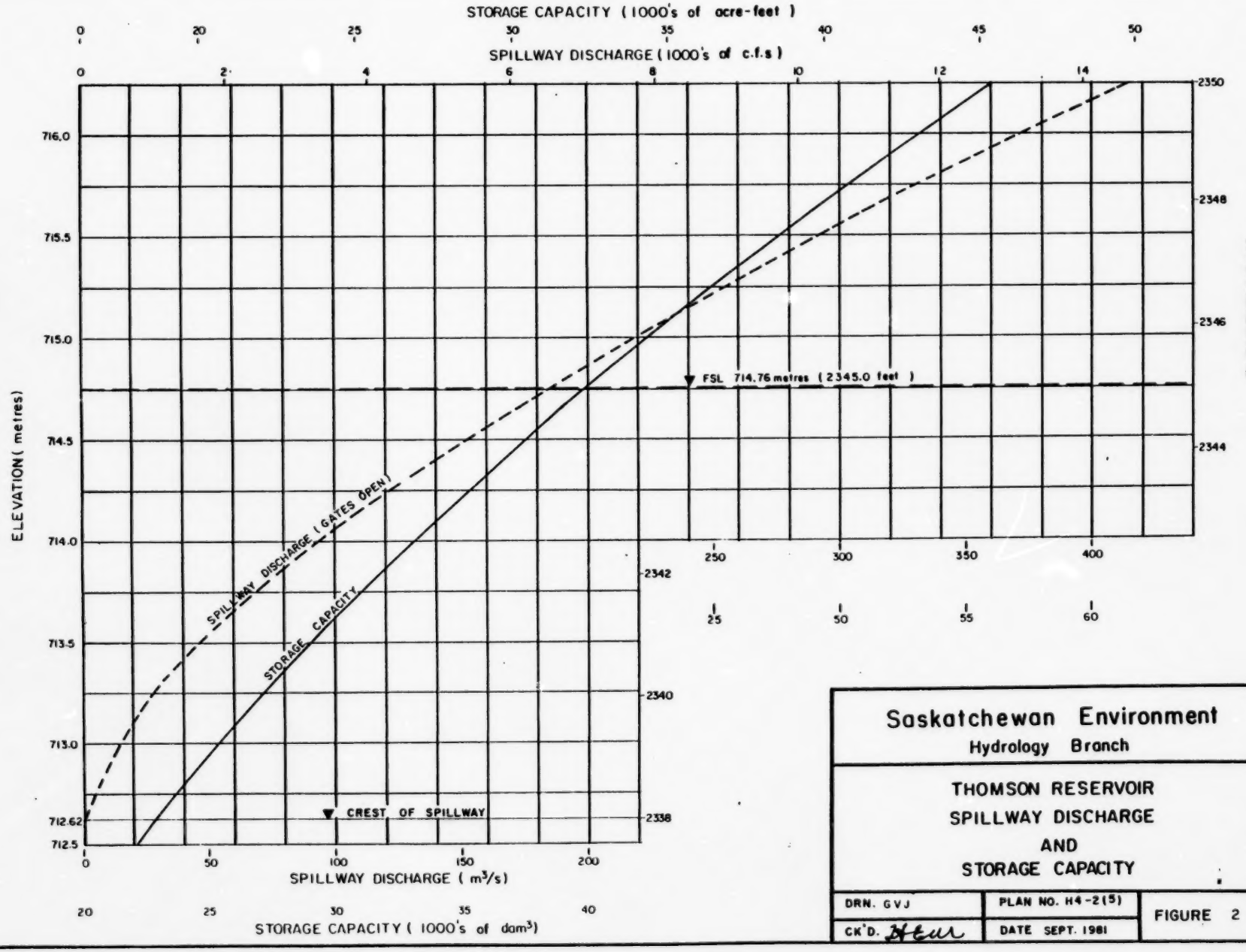
Data on file for former hydrometric station 5JA-1, located a short distance downstream from the present Thomson Reservoir, indicate that the river there will overflow its banks at 5250 cfs or 147 m^3/s. At other locations in the Gravelbourg area, overbank flooding may occur at even lower flows than at the former station. In Table 2, a discharge of 5000 cfs or 142 m^3/s was used as an approximation of full channel flow in the Gravelbourg area. Flows above this amount would likely raise concerns about overbank flooding, and/or continued inundation of the river flood plain. The duration of flow above this magnitude can, therefore, be of practical concern to residents in the Gravelbourg area downstream from Thomson Reservoir.



Saskatchewan Environment
Hydrology Branch

KEY MAP
WOOD RIVER BASIN ABOVE THOMSON RESERVOIR

Drn	Date June 1981	Figure 1
Ck'd	Plan No. H4-2(4)	

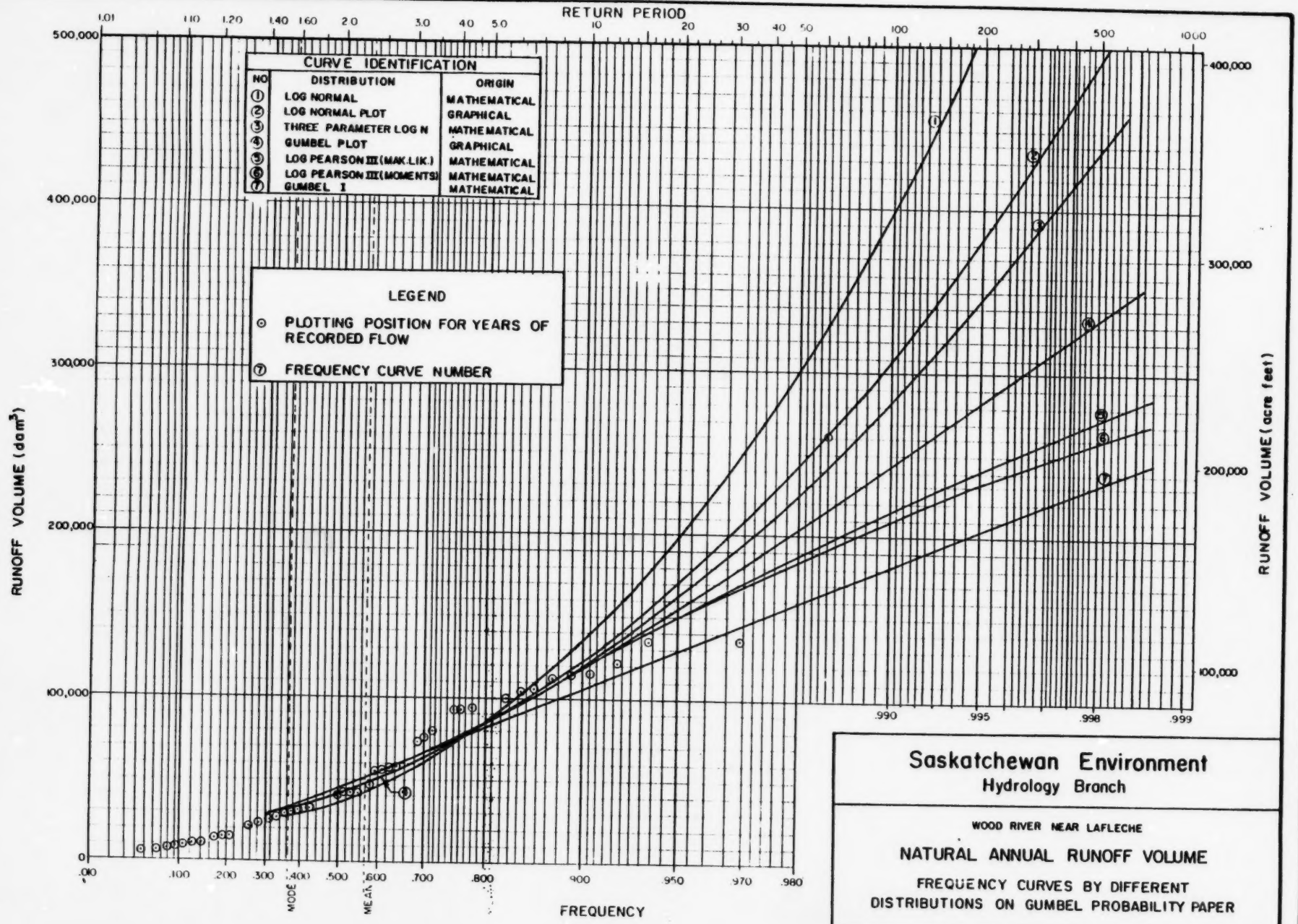


Saskatchewan Environment
Hydrology Branch

THOMSON RESERVOIR
SPILLWAY DISCHARGE
AND
STORAGE CAPACITY

DRN. GVJ	PLAN NO. H4-2(5)	FIGURE 2
CK'D.	DATE SEPT. 1981	

8-09-79-2



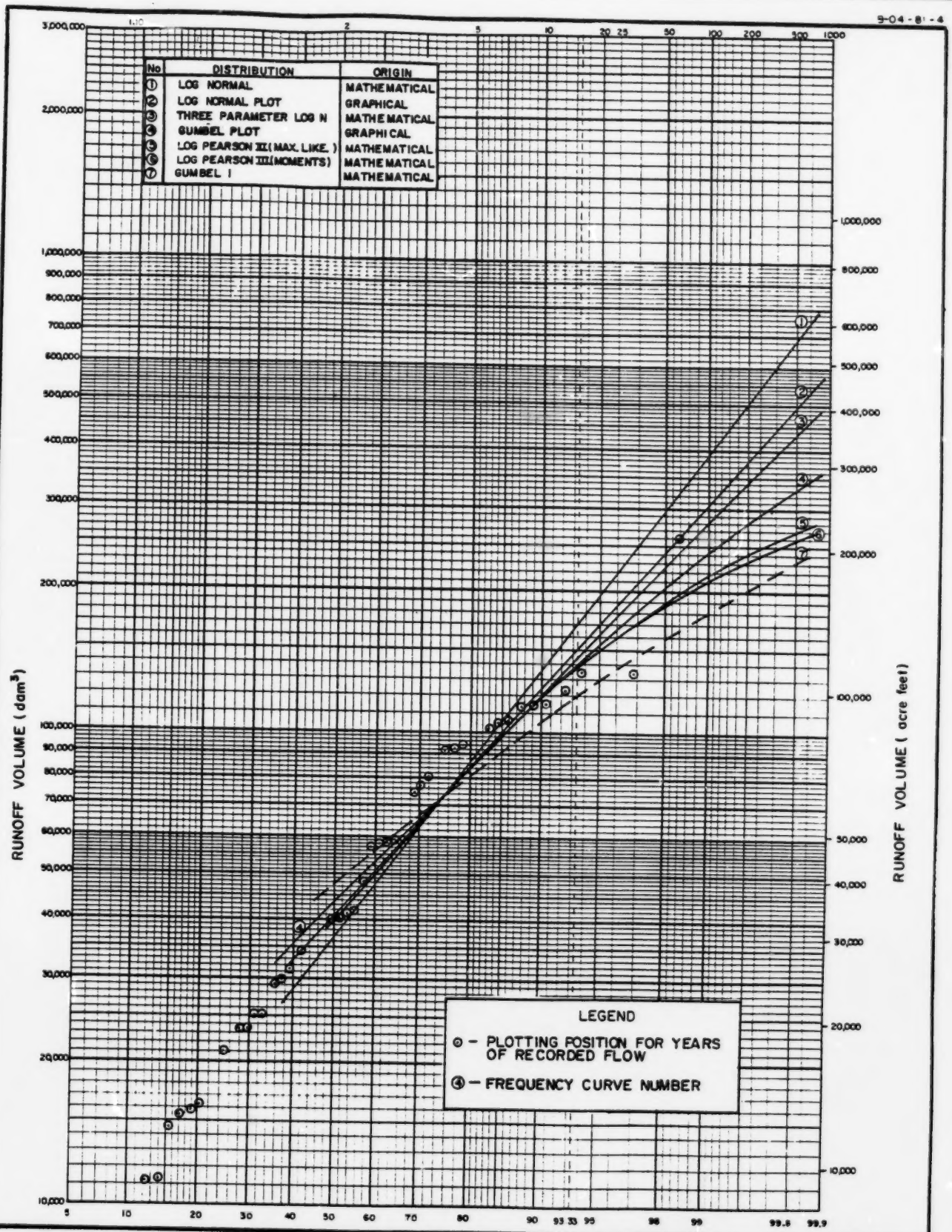
Saskatchewan Environment
Hydrology Branch

WOOD RIVER NEAR LAFLECHE

NATURAL ANNUAL RUNOFF VOLUME

FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON GUMBEL PROBABILITY PAPER

Drn: GVJ	Date: Sept / 81	Figure 3
Ckd [illegible]	Plan No. H4-2(6)	


No. DISTRIBUTION ORIGIN
① LOG NORMAL MATHEMATICAL
② LOG NORMAL PLOT GRAPHICAL
③ THREE PARAMETER LOG N MATHEMATICAL
④ GUMBEL PLOT GRAPHICAL
⑤ LOG PEARSON III (MAX. LIKE.) MATHEMATICAL
⑥ LOG PEARSON III (MOMENTS) MATHEMATICAL
⑦ GUMBEL I MATHEMATICAL
RUNOFF VOLUME (dam³)
RUNOFF VOLUME (acre feet)
LEGEND
⊙ – PLOTTING POSITION FOR YEARS OF RECORDED FLOW
④ – FREQUENCY CURVE NUMBER

Saskatchewan Environment
Hydrology Branch

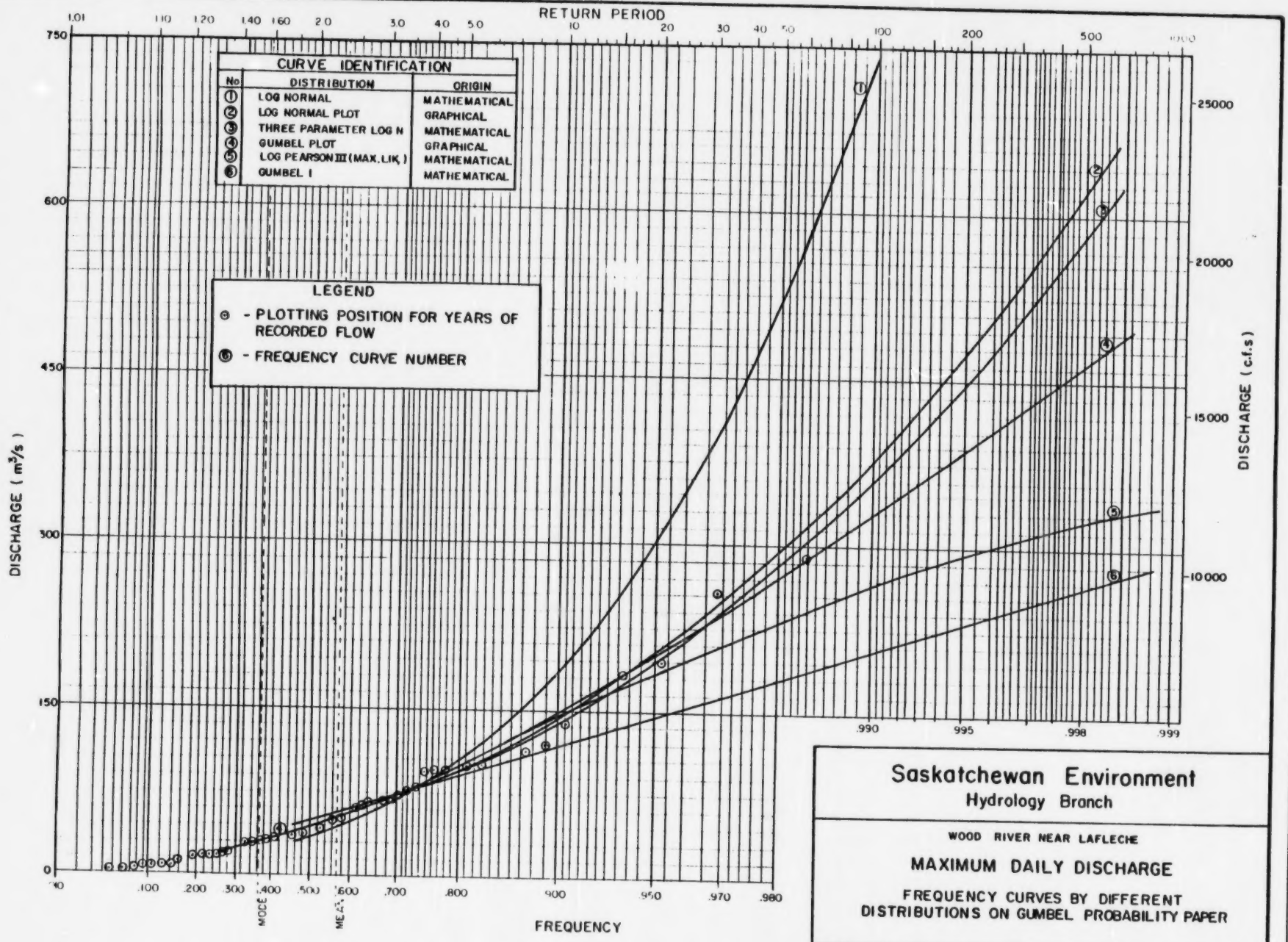
Drn. GVJ	Date: Sept 1981
Ck'd. [illegible]	Plan No. H4-2(7)

WOOD RIVER NEAR LAFLECHE

NATURAL ANNUAL RUNOFF VOLUME

FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON LOG PROBABILITY PAPER

Figure 4



Saskatchewan Environment
Hydrology Branch

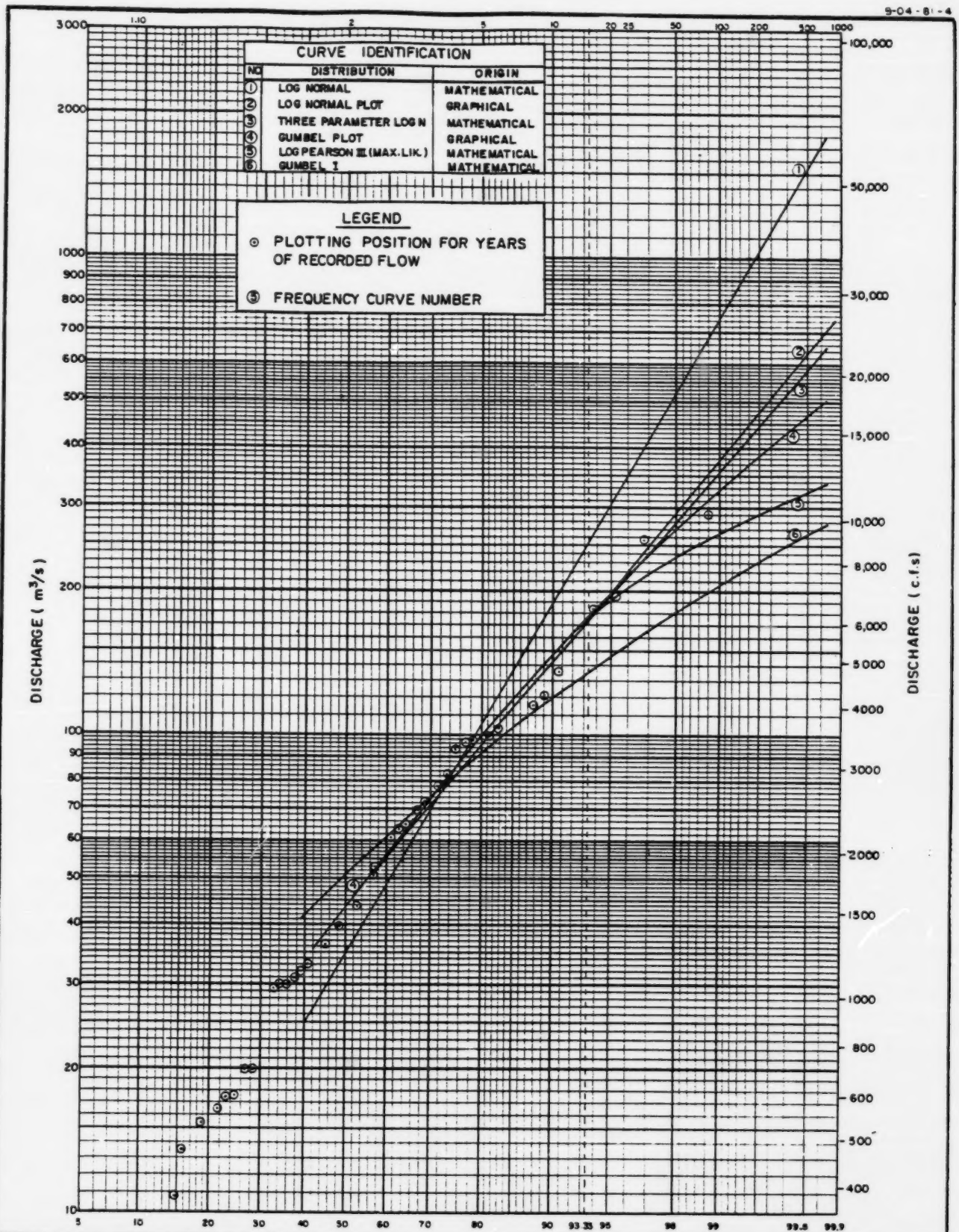
WOOD RIVER NEAR LAFLECHE

MAXIMUM DAILY DISCHARGE

FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON GUMBEL PROBABILITY PAPER

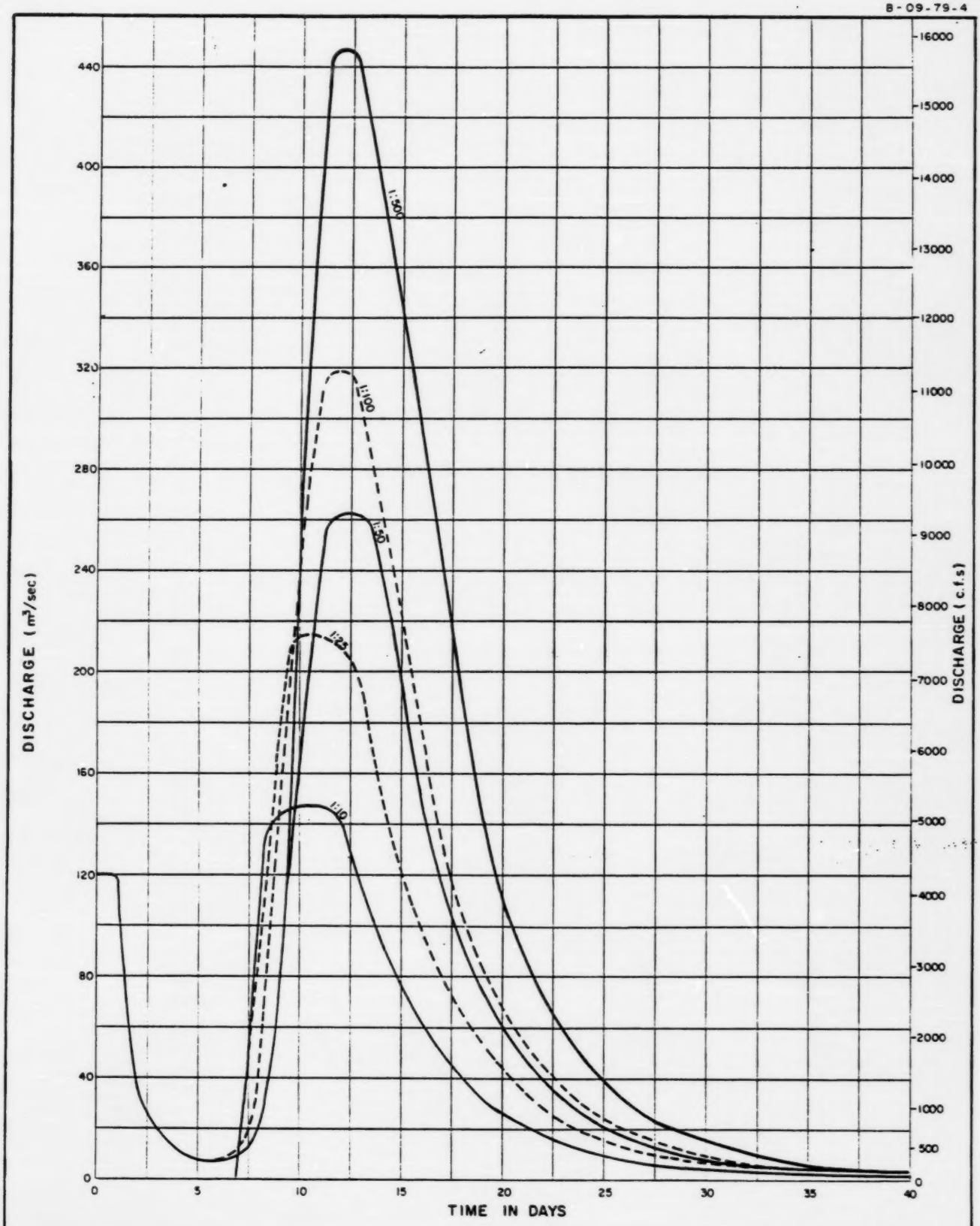
Drn: GVJ	Date: Sept / 81	Figure 5
Ckd [illegible]	Plan No. H4-2(8)	

9-04-81-4



Saskatchewan Environment Hydrology Branch	WOOD RIVER NEAR LAFLECHE MAXIMUM DAILY DISCHARGE FREQUENCY CURVES BY DIFFERENT DISTRIBUTIONS ON LOG PROBABILITY PAPER	Figure 6
Drn. GVJ / Date: Sept 1981 Ck'd. / Plan No. H4-2(9)		

B-09-79-4



Saskatchewan Environment Hydrology Branch		WOOD RIVER BELOW THOMSON RESERVOIR FLOOD HYDROGRAPHS FOR THE 10, 25, 50, 100 AND 500 YEAR FLOOD EVENTS	Figure
Drn.: GVJ	Date: JUNE 1981		7
Ck'd.: [illegible]	Plan No. H4-2 (10)		